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Research

Breast Implants Decrease Chest Wall Trauma in Low-speed, Unrestrained Motor Vehicle Crash: An Experimental Model

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Introduction: Breast implants improve quality of life in patients seeking improved breast aesthetics, and are known to minimize human injury in the less common scenario of penetrating trauma. People commonly sustain rib and sternum fractures and thoracic injury in motor vehicle crashes (MVC), a form of blunt traumatic injury. Whether breast implants minimize injury during MVC is unknown. This study examines the potential protective effect of breast implants in low speed, unrestrained MVC.

Methods: Control (medical gel) and implant (medical gel with embedded breast implant) blocks were subjected to load approximating a low speed, 10mph MVC (n=12 blocks per group). Colormetric pressure film measured pressure at the neo-chest wall position in response to load, across the gel block base. Maximum pressure and average pressure across the gel block base were compared, by group.

Results: Presence of an implant significantly decreased, by 22.8%, maximum pressure experienced by the neo-chest wall (333.0±58.7 psi vs 431.6±37.3 psi, p=0.0006). Average pressure experienced by the neo-chest wall across the gel block base was also significantly decreased, by 28.1%, in the implant group (53.4±5.6 psi vs 74.3±15.7 psi, p=0.0017). Subjective analysis of all implant and control blocks supported an overall reduction in pressure for the implant group.

Conclusions: Presence of a breast implant decreased maximum pressure at the chest wall by 23%, and average pressure by 28%. Patients with breast implants involved in low speed, unrestrained MVC may be less likely to sustain rib and sternum fractures and thoracic injury, when compared to patients without implants. *(Plast Reconstr Surg Glob Open 2023; 11:e5161; doi: 10.1097/GOX.0000000000005161; Published online 26 July 2023.)*

INTRODUCTION

Breast implants have both expected and unexpected benefits. Breast implants are known to improve quality of life in women seeking improved breast aesthetics and in reconstruction.[1–4] In addition to this expected benefit, breast implants have also been associated with lower overall breast cancer risk,[5] smaller breast cancer tumor size at detection,[6] improved breast cancer immunosurveillance via higher antibody recognition of mammaglobin-A and mucin-1,[7] and minimization of human injury in firearm trauma[8–13] and animal attacks.[9]

Breast implants can minimize human injury in penetrating trauma,[8–13] which is fortunately rare. Blunt traumatic injury is more common. Breast implants are known to deform or rupture as a consequence of blunt trauma.[14] This study sought to understand whether breast implants may provide a protective effect in patients who experience blunt chest trauma during a low-speed motor vehicle crash (MVC).

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Low-speed [<10 miles per hour (mph)] MVCs are incredibly common. Rear-end MVCs comprise nearly 30% of all MVCs, or ~1.7 million accidents per year; over 80% of rear-end collisions occur when the lead vehicle is either stopped or moving slowly. These data support that 1.4 million low-speed MVCs occur per year.[15,16] A 10-mph MVC creates forces exceeding 1.9 kN, which is the threshold of rib fracture strength.[17] (**See text, Supplemental Digital Content 1,** which displays the math behind the statement. **http://links.lww.com/PRSGO/C698**.)

The minimum threshold for front airbag deployment is impact into a rigid wall at ~12 mph, and thus, common safety measures do not protect unbelted passengers in low-speed MVC.[16]

Over 1.3 million people annually die from road traffic accidents worldwide.[18] In the United States, approximately 6.8 million MVCs occur annually, resulting in nearly 43,000 deaths.[19,20] Stated differently, MVCs are common—approximately one in 50 persons will be involved in an MVC annually. Breast implants are increasingly common, with one estimate suggesting that one in 26 American woman has breast implants.[21] An estimated 200,000 and 1.6 million breast augmentation surgeries, respectively, occur in the United States[22] and worldwide[23] annually, and over 206,000 implants are placed nationally in reconstruction.[22] Independently, MVC and breast implants are common amongst Americans. Many women with breast implants are involved in MVCs every year, but whether these implants provide incidental protection against blunt traumatic injury remains unknown.

Breast implants may significantly alter the magnitude or distribution of pressure experienced by the chest wall after blunt trauma sustained in MVCs. This, in turn, could provide a protective effect against rib or sternum fracture, lung contusion, or other chest wall injury. This experimental study simulates a low-speed, unrestrained MVC in patients with and without breast implants. We hypothesized that the presence of breast implants would significantly reduce pressure experienced by the chest wall, when compared with the absence of implants.

METHODS

Creation of Augmented Human Breast and Nonaugmented Breasts

Custom medical gel-breast implant constructs were created to simulate an augmented human breast and nonaugmented human breasts. Constructs were created by Humimic Medical (Fort Smith, Ark.), a specialist synthetic medical gel and ballistics gel company with expertise in human model fabrication. Ballistics gelatins are regularly used as soft tissue surrogates in experimental models of blunt trauma. Specifically, 10% gelatin blocks have been used in models simulating nonpenetrating blunt thoracic injury,[24–26] blunt trauma to the brain,[27,28] and blunt trauma to the eye.[29] Models using gelatin blocks as soft tissue surrogates with impactor head load have previously been published.[27,28]

> **Takeaways**
>
> **Question:** Can breast implants protect women in low speed (<10mph) motor vehicle crashes against rib & sternum fracture and chest wall injury?
>
> **Findings:** This experimental study used a drop tower to provide 1.9kN of force (a known inflection point for rib fracture) to a simulated human breast and augmented human breast. In the implant group, maximum pressure experienced by the chest wall decreased by 23% (333.0 ± 58.7 psi vs 431.6 ± 37.3 psi, p=0.0006).
>
> **Meaning:** Breast implants plausibly decrease forces experienced by the chest wall in low speed (<10mph) motor vehicle crashes, and likely decrease risk of rib & sternum fracture.

Blocks were created to include the same amount of medical gel (2155 cm^3), with or without an implant. Implant blocks were created using a Smooth Round Ultra High Profile 800-cm^3 implant (Mentor, Irvine, Calif.). The block contained an 800-cm^3 implant embedded in 2155 cm^3 of medical gel with a 16-cm (6.3-in.) square base, and a resultant height of 11.7 cm. One centimeter of gel thickness was behind the implant, modeling subfascial augmentation. Control blocks included 2155 cm^3 of medical gel with a 16-cm (6.3-in.) square base, with a resultant height of 8.4 cm (Fig. 1).

Preliminary Experiments

Preliminary experiments provided sample size calculation data and determined whether a dynamic recording Tekscan (Norwood, Mass.) pressure mapping sensor, which collected digital data at 100 Hz, or Fujifilm Prescale (Fujifilm, Minato, Japan) pressure sensitive film, which recorded maximum pressure analog data, would be the optimal data-acquisition strategy.

Data capture was performed using a Tekscan pressure mapping sensor (Model 5151) and the Tekscan I-Scan system. The pressure sensor was placed under the gel block, in the simulated chest wall (neo-chest wall) position. The pressure sensor acquired digital data at 100 Hz.

Load was provided by an Instron Dynatup 9520 drop tower (Instron, Norwood, Mass.) at the School of Mechanical Engineering at the University of Washington. The tower dropped a 7.46-kg weight with an impact velocity of 4.25 m/s. The impactor had measured 4.25 × 1 inch with rounded edge contact surfaces on the impactor head. The Dynatup tower acquired data from the impactor head at 10,000 Hz.

Impactor head data for implant blocks showed widely variable maximum load, ranging from 6.3 kN to 8.0 kN. This was unexpected, given that the drop tower was calibrated on the day of the experiment, with constant mass and impact velocity. Impactor head data also showed load increased at 2.3 kN per millisecond. [**See graph, Supplemental Digital Content 2,** which displays preliminary data. Impactor head data for 12 implant blocks in

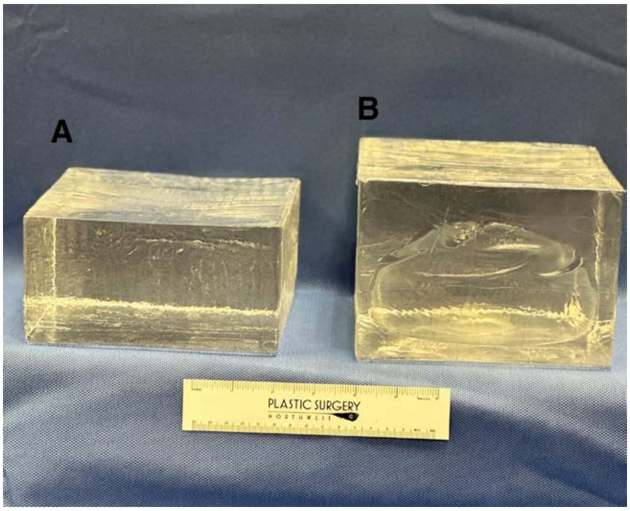

Fig. 1. Gel constructs. Medical gel (A) and medical gel-breast implant (B) constructs.

preliminary study, showing widely variable (6.3–8.0 kN) maximal load. **http://links.lww.com/PRSGO/C699**.]

Given the expected maximum load range and the rate of load application, the 100-Hz data-acquisition speed of the Tekscan I-scan pressure sensor was insufficient. Thus, an analog data-capture strategy was used for the definitive experiment.

Definitive Experiment

The definitive experiment measured pressure using Fujifilm Prescale pressure sensitive film (Fujifilm, Minato, Japan). The film measures pounds per square inch (psi) via embedded microcapsules, which burst at prescribed pressures, producing a local color change.[30] Pressure sensitive film is widely used to quantify pressure in experimental studies of soft tissue injury or alteration.[31,32] The pressure sensitive film was placed under the gel block, in the neo-chest wall position (Fig. 2).

Load was provided by an Instron Dynatup 9520 drop tower. The tower dropped a 7.46-kg weight with an impact velocity of 4.25 m/s. The impactor had measured 4.25 × 1 inch, and the edges on the contact surface of the impactor were rounded. The load applied (1.9 kN) was representative of the load for a 70 kg patient involved in a 10 mph, unrestrained MVC (**Supplemental Digital Content 1, http://links.lww.com/PRSGO/C698**).

The 1.9-kN load was thoughtfully selected, as it is a recognized transition point in rib fracture strength. Prior work has utilized postmortem human rib cages and impactor head rigid impact, modeling forces from a rigid object (steering wheel) as opposed to airbags. These data support that an impact force of 1.6–1.9 kN will fracture between four and 13 ribs. Thus, 1.9-kN force represents the upper limit of rib strength integrity, as it fractures a portion (but not all) of ribs. This statement is supported by data demonstrating that increased force to 2.6 kN will fracture up to 16 ribs.[17]

Colormetric density data on the Prescale film was analyzed by FujiFilm Pressure Distribution Mapping System for Prescale (Fujifilm, Minato, Japan). A 6-inch (15.24 cm) square centered on the impactor head location was identified; this square was intentionally chosen to be slightly smaller than the 6.3-inch (16 cm) square gel block base, to eliminate edge shear artifact. Within the square, maximum pressure (psi) and average pressure (psi) across the 6 × 6 inch square were identified using the Mapping System for Prescale software.

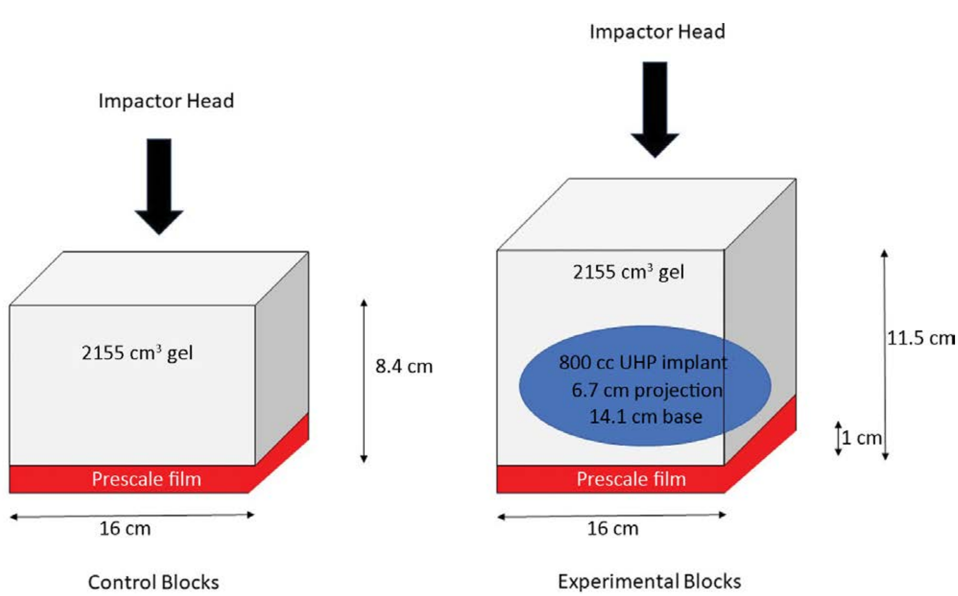

Fig. 2. Experimental design.

Analysis Plan

FujiFilm Pressure Distribution Mapping System for Prescale determined maximum pressure (psi) and average pressure (psi) across the 6×6 inch square. Each dependent variable is continuous, and a paired *t* test compared maximum pressure and average pressure, by group (implant block versus control block).

Eleven control blocks and one implant block saturated at the upper limit of Fujifilm LLW pressure film (444 psi). For these blocks, maximum pressure was recorded as 444 psi for analysis, though it very likely exceeded this value (see "Limitations" section).

Three of 12 control gel blocks (blocks 2, 9, and 10) had evidence of shear. Analyses were performed in a stratified fashion: analysis 1 dropped these blocks and their matched pairs, treating them as outliers, and analysis 2 included all blocks and their matched pairs. This planned stratified analysis considered whether the outlier shear force blocks impacted directionality and/or magnitude of the observed result. Scanned images of implant and control blocks were displayed side-by-side for subjective analysis.

Sample Size Calculation

Preliminary data from the Instron Dynatup 9520 impactor head showed that at peak load, energy was significantly increased in implant versus control groups (55.86±3.78J versus 48.12±4.37J, $P < 0.005$). (**See graph, Supplemental Digital Content 3,** which displays preliminary data. Impactor head data showing energy at peak load was significantly higher in implant versus control group. **http://links.lww.com/PRSGO/C700**.)

We assumed that the magnitude of energy absorption (seen using impactor head data) would mirror the decreased pressure experienced at the neo-chest wall. Alpha was set at 0.05. With these assumptions, a sample size of 11 per group would provide 99% power to detect the difference. The definitive experiment was performed using 12 implant blocks and 12 control blocks, to exceed the sample size calculation.

RESULTS

Implant and control gel blocks were created according to specification (Fig. 1). Test drops showed the Prescale film-gel block interface was prone to shear, manifested as partial separation between the film and gel block after initial impact with sliding/shear pattern on the Prescale film. In the definitive experiment, the film was lightly taped to all blocks to minimize shear (Fig. 3). [**See Video (online),** which displays impactor head applying load to control (left) and implant (right) gel blocks.] Figure 4 shows a representative implant and control pair (pair 12).

Despite taping, three of 12 control blocks showed evidence of shear. Per the analysis plan above, the initial analysis dropped these blocks and their matched controls. Zero of 12 implants in the experimental group ruptured.

Presence of an implant significantly decreased maximum pressure experienced by the neo-chest wall. Specifically, there was a significant difference in maximum pressure between implant and control groups (333.0±58.7 psi versus 431.6±37.3 psi, $P = 0.0006$; n = 9 pairs); this equates to a 22.8% reduction in maximum pressure experienced (Fig. 5).

Presence of an implant significantly decreased average pressure experienced by the neo-chest wall across the 6×6 inch base. Specifically, there was a significant difference in average pressure across the 6×6 inch base between

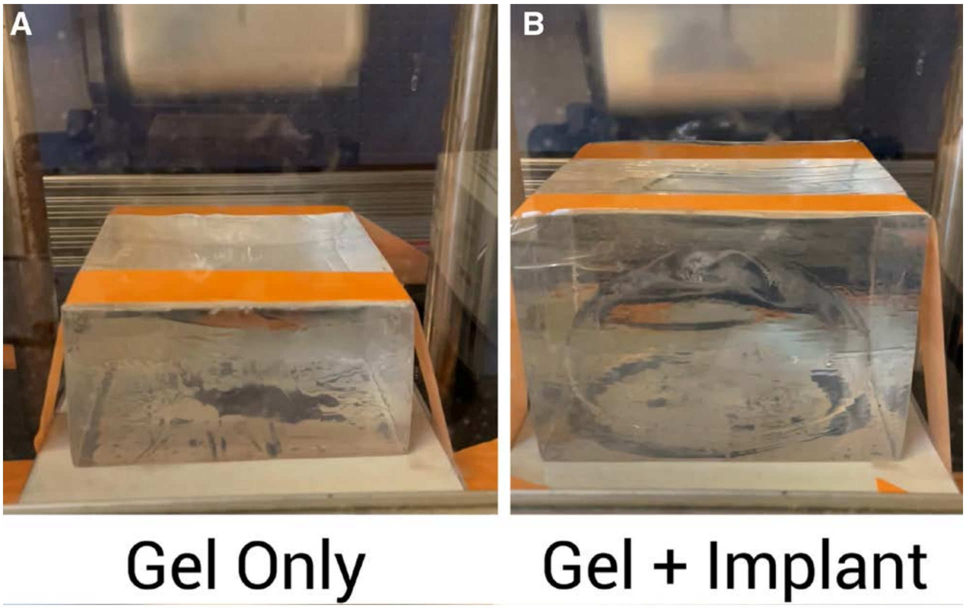

Fig. 3. Experimental design, with control (A) and implant (B) gel blocks. **Video 1** shows the impactor head delivering force in slow motion.

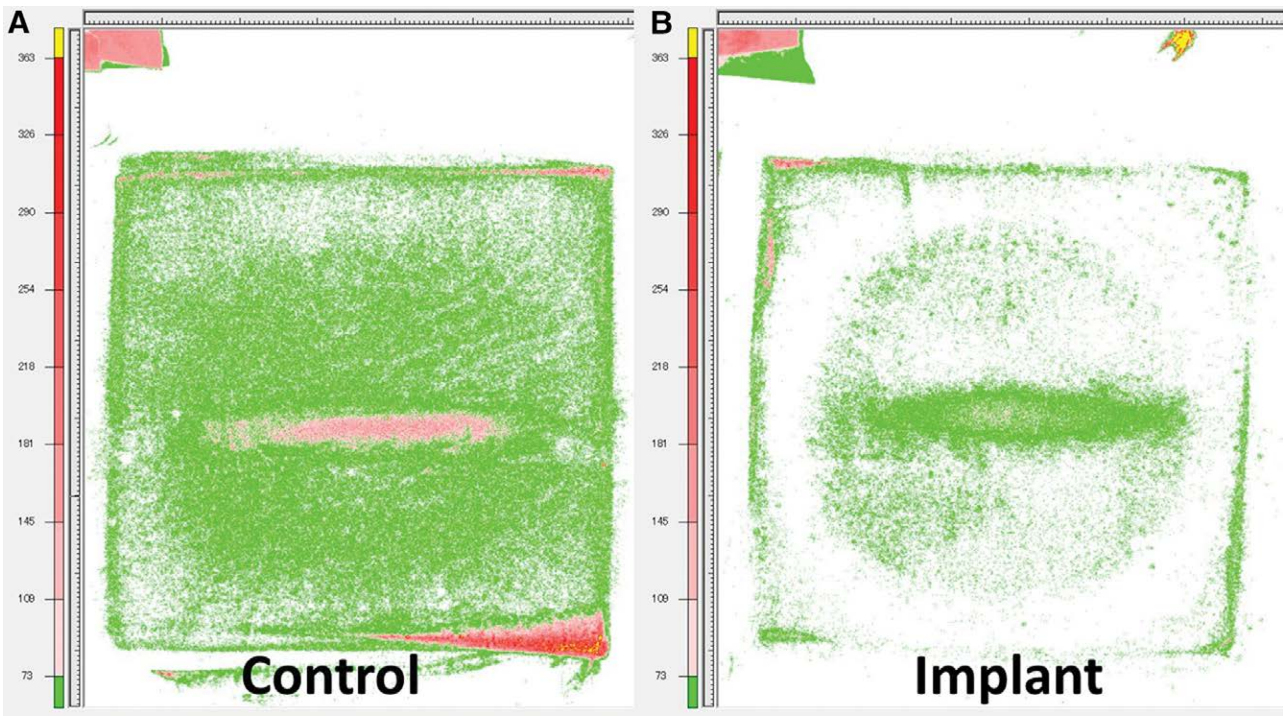

Fig. 4. Pressure films. Representative implant (A) and control (B) pair. Color bars at the left side of the image indicate pressure (psi).

implant and control (53.4±5.6 psi versus 74.3±15.7 psi, P = 0.0017; n = 9 pairs); this equates to a 28.1% reduction in average pressure experienced (Fig. 5).

Inclusion of the three control blocks with shear and their matched implant blocks increased the effect size but did not impact directionality. Maximum pressure experienced by the neo-chest wall was significantly decreased in implant versus control blocks (331.6±53.4 psi versus 434.7±32.3 psi, P < 0.001; n = 12 pairs); this correlates with a 23.7% reduction in maximum pressure experienced. Average pressure across the 6×6 inch base was also significantly decreased in implant versus control blocks (52.8±5.0 psi versus 110.0±69.8 psi, P = 0.0097; n = 12 pairs); this correlates with a 52% reduction in average pressure experienced. Subjective analysis, including side-by-side of all 12 matched pairs, supports that pressure is generally decreased in implant versus control blocks (Fig. 6).

DISCUSSION

Breast implants produce a 23% decrease in maximum pressure experienced by the chest wall, as shown in this experimental model of low-speed, 10-mph unrestrained MVC—a speed at which air bags would not deploy, and a force at which rib fracture would occur. This suggests that patients with breast implants may be protected from chest wall injury, such as rib and sternal fractures or lung contusions, when compared with the general unrestrained population involved in low-speed MVC.

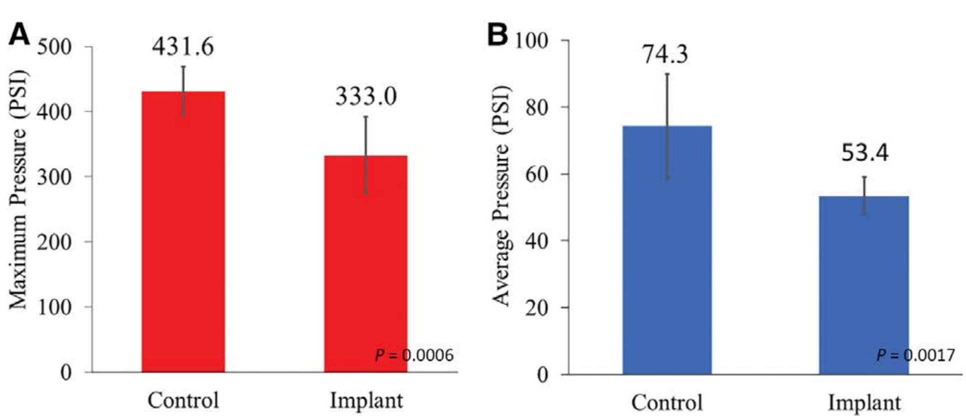

Fig. 5. Pressure graphs. Maximum pressure (A) and average pressure (B) in control vs implant blocks.

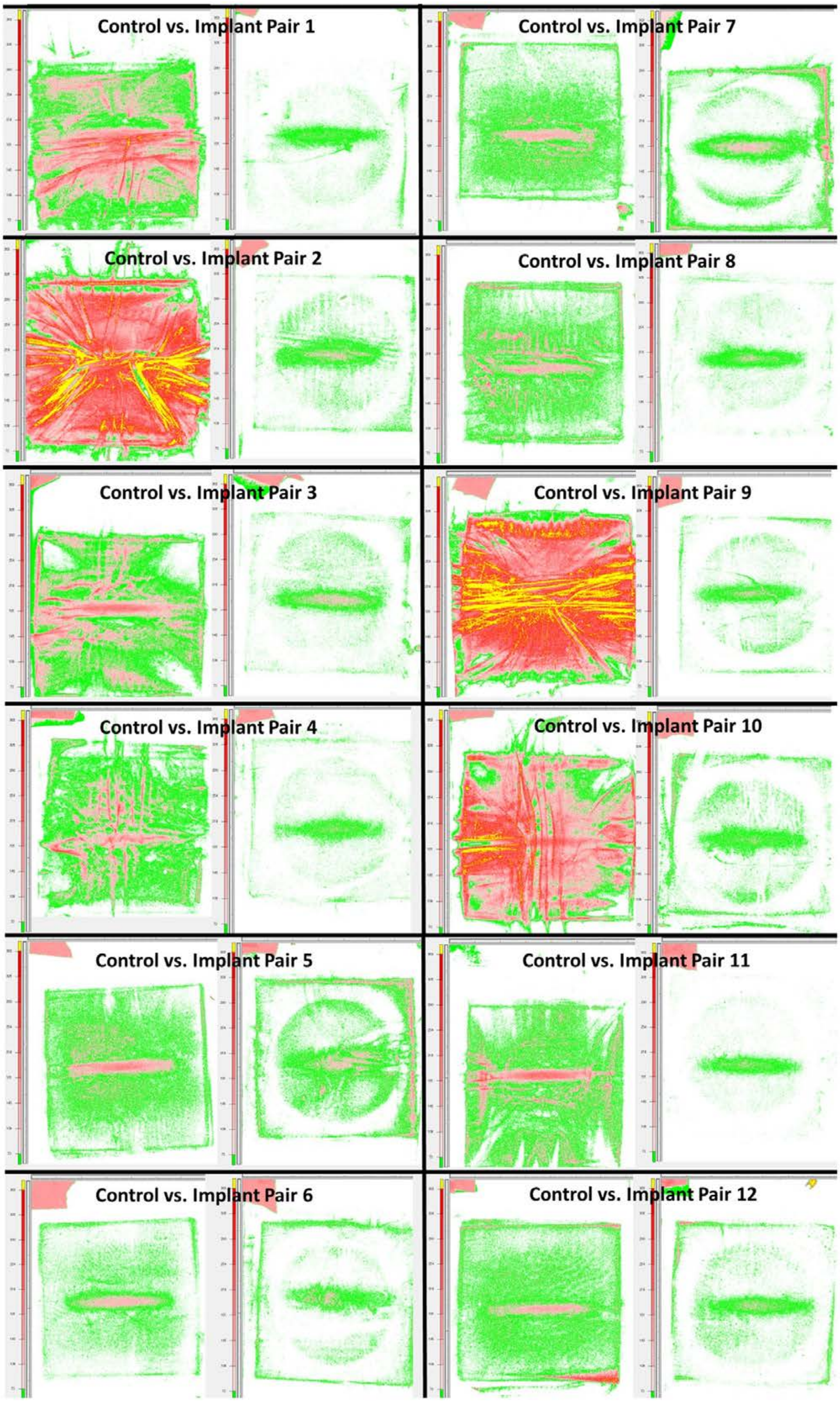

Fig. 6. Visual pressure data for 12 implant and control pairs. Color bars at the left side of the image indicate pressure (psi).

Relevance of Model

Chest injuries occur in MVC despite the presence of safety features, including airbags and seat belts.[33,34] Airbags do not typically deploy until speeds exceed 12 miles per hour—a relevant fact in this experimental model of 10-mph MVC.[16] Among 19 states reporting data, 10% of drivers do not routinely use front seat-belts during the daytime.[35] Disproportionately, unrestrained motor vehicle occupants sustain injury in accidents; 46% of fatally injured occupants are not restrained.[35] Thus, thoracic injuries occur with regularity in patients involved in MVC, despite seat belts and airbags.

Nearly 7 million motor vehicle crashes occur in the United States every year, making this a common event for Americans (~1:50 annual incidence).[19,20] Similarly, breast implants are common in Americans, with an estimated prevalence of 1:26 women.[21] The frequent intersection of these two conditions is inevitable. These data show that the presence of breast implants minimizes chest wall pressures in this experimental model, which could have relevance in low-speed, unrestrained motor vehicle crashes. This would likely decrease the risk of rib or sternum fractures, lung contusion, or thoracic injury.

The authors are not suggesting that breast implants in any way replace seat belts, appropriate restraint devices, and/or airbags. Rather, this study acknowledges the baseline conditions that:

1. One in 50 Americans are involved in an MVC annually[19,20];
2. Over 1.4 million low-speed MVCs occur annually[15,16];
3. One in 10 motor vehicle occupants do not routinely use seat belts[35];
4. Rib fractures occur at 1.9-kN force,[17] which is generated for an average weight human involved in 10-mph MVC; and
5. Airbags do not deploy until speeds exceeding 12 mph are reached.[16]

These facts make the presented model of low-speed (10 mph), unrestrained MVC particularly relevant to the general population, including those with breast implants placed during augmentation or reconstruction.

Positive Impact of Breast Implants

Breast implants, placed for aesthetic or reconstructive purposes, improve quality of life.[1–4] Emerging data support that breast implants may be life-prolonging in some women. Meta analysis data show that women with cosmetic breast implants have significantly decreased risk (0.63, 95% CI 0.56–0.71) for breast cancer, when compared with age-matched controls who do not have breast implants.[5] Fracol and colleagues have identified a plausible immunologic mechanism via higher antibody recognition of mammaglobin-A and mucin-1 in women with breast cancer; they suggest that breast implants may invoke an immune response allowing breast cancer immunosurveillance.[7] Women with implants may self-identify cancers earlier,[6] compared with patients without implants, plausibly due to easier detection on self-examination.

This work builds upon an increasing body of research showing unexpected and direct benefits of breast implants in traumatic injury. Breast implants have been correlated with injury prevention or injury minimization in firearms injuries[8,10–13] as well as animal attacks.[9] An experimental model of gunshot injuries previously published demonstrated that the presence of a breast implant decreased soft tissue penetration by 20.6%, supporting the plausibility of implant-mediated protection.[8] Admittedly, gunshot injuries and animal attacks are rare events for most Americans—but most Americans drive (or are the passengers in) a motor vehicle regularly. Thus, the presented data are relevant to the over 400,000 Americans[22] and 1.6 million patients worldwide[23] who have breast implants placed every year, and the tens of millions worldwide who already have breast implants in place.

Limitations

The experimental model was limited by shear forces, observed more commonly in control (three of 12 blocks) versus implant (zero of 12 blocks) groups. The initial analysis, including nine matched pairs, showed a 23% decrease in maximum pressure and a 28% reduction in average pressure across the 6×6 inch base. Inclusion of the three shear control blocks and their matched pairs increased the magnitude of the relationship but not the direction. For this reason and reasons below, we are confident in the direction of the effect, but acknowledge that the reported data may underestimate the effect size.

Prescale LLW film (optimal range 71–395 psi, maximum 444 psi) was chosen for this experiment, based on both preliminary data and day-of-experiment test drops on blocks identical to control and implant blocks. The majority (11 of 12) of control blocks and a minority (one of 12) of implant blocks had at least one yellow pixel, correlating with a maximum pressure of 444 psi or more. For the analysis, these values were set as 444 psi, the maximum pressure demonstrated to be present. The maximum pressure (and average pressure across the 6×6 inch base), particularly in the control group, was likely higher than observed. Thus, the reported 23% decrease in maximum pressure and 28% reduction in average pressure across the 6×6 inch represents the low end of the effect size, and likely underestimates the true effect size. Although a higher pressure maximum Prescale film (LW film, pressure range 350–1400 psi) is available, it would have a lower resolution for the implant group (eight of the 12 implant blocks had a maximum pressure <350 psi).

This study utilized ultra-high projecting 800-cc implants embedded in 2155 cc of medical gel. This implant size was chosen to maximize the potential observed effect using the largest implant with maximum vertical depth and to simultaneously allow the construct to fit within the space between the drop tower's impactor head guide arms. The experimental model produced 3.8 cm of coverage superficial to and 1 cm deep to the implant as intended, which would not be uncommon in a larger-breasted patient seeking augmentation. The observed 23% reduction in maximum pressure might be different if a smaller volume or less projecting implants were used. We acknowledge that an 800-cc implant under 2155 of breast tissue is a less-common augmentation pattern. Using a 16×16cm square base and a square gel block, the minimum gel volume for complete implant coverage, including 1cm on all sides, is 1427 cc. Future models might use a custom mold producing a conical gel shape surrounding the implant to minimize gel volume. This study clearly demonstrates that an 800-cc breast implant can decrease chest wall pressures in an experimental model of a low-speed MVC. Importantly, future work could use more common implant sizes for augmentation (300–400 cc) to quantify the protective effect of smaller volume implants in a similar model. This "next step" experiment would produce more clinically relevant data than the presented model.

CONCLUSIONS

This experimental model shows that breast implants can decrease pressure experienced by the chest wall in low-speed, unrestrained motor vehicle crash. Specifically, maximum pressure at the chest wall was decreased by 23%, and average pressure by 28%, in the implant group. Patients with breast implants involved in low-speed, unrestrained MVCs may be less likely to sustain rib or sternum fractures or thoracic injury, when compared with patients without implants.

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DISCLOSURES

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Dr. Pannucci received an honorarium from Sientra in September 2022 for speaking on venous thromboembolism in breast reconstruction patients.

AJC and KMC are married. AJC and CJP are brothers-in-law.

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